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Addition of Transition Metal Ion CMP Slurry for Forming Ultra-Flat SiC Crystal

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Abstract. The modified SiC slurry for CMP process was proposed in order to obtain high-quality surface of 150 mm SiC wafer and then tried to explain the mechanism of the effect of added transition metal ion to improve polishing characteristics of SiC crystal substrate. SiC substrate with using modified slurry exhibited slightly higher MRR value and lower platen temperature than those with using commercial slurries. The addition of transition metal ion into the slurry enhanced oxidation efficiency of SiC crystal surface and improved MRR and the quality of SiC surface.

Introduction

SiC Single crystal has a high critical breakdown electric field, high thermal conductivity, high saturated drift carrier speed, and other excellent characteristics. As a substrate material, SiC is required to have an ultra-flat and ultra-smooth surface to meet the requirements for epitaxial film growth and it must be free of defects and damage, because its accuracy directly determines the performance of semiconductor devices [1-3]. Since SiC is well-known for its exceptionally high hardness, brittleness and inertness, the current chemical mechanical polishing (CMP) process of SiC substrate usually suffers from high machining costs and low throughput. The material removal rate (MRR) and the quality of finished wafer surface which includes roughness, defectivity and scratches are the two major factors on a SiC CMP process. The property of slurry has an important impact on determining both factors. Previous research has been performed to study the abrasive and oxidizer within the slurry and the SiC substrate surface evaluated the MRR of 6-inch SiC wafers by adding transition metal ion(Me) as strong oxidant in slurry [4-8].

In this study, the modified SiC slurry for CMP process was proposed in order to obtain high-quality SiC surface of 150 mm SiC wafer and then tried to explain the mechanism of the effect of added transition metal ion(Me) to improve polishing characteristics of SiC crystal substrate. The MRR values and quality of SiC surfaces prepared with modified slurries with those of conventional slurries without added transition metal ions were systematically compared in terms of MRR values and surface quality.

Experiments

150 mm-SiC wafers (4° off-axis, n-type, 350 μm in thickness) fabricated from the common SiC ingot were used in this study. Actual CMP process for both faces(Si-/C-face) of SiC substrate was performed with using conventional slurries provided from commercial products and the modified slurry (KC-Tech.Co Ltd). SiC substrates were polished for 1hr with a membrane polishing head of ACCRETECH ChaMP211 CMP system and the slurry flow was 150 ml/min. MRR values and surface roughness data of CMP-processed SiC substrates with using different slurries were systematically compared. The surface morphology and scratch of SiC substrates after the CMP process were analyzed by an atomic force microscope (Park Systems, XE-150) and Candela 8520 (KLA Tencor), respectively.

Result and Discussions

Fig. 1 exhibited schematic diagram for explaining a role of added transition metal ion into modified SiC slurry to enhance SiC polishing rate. Reaction of MnO_4^- with SiC substrate made soluble SiO_3^{2-} and CO on the surface of the SiC substrate, indicating that SiC surface can be polished by the dissolution. Transition metal ion Me^{3+} simultaneously reacts with MnO_2 and then regenerated to MnO_4^-, which can participate in oxidation process on SiC surface again. That is transition metal ion(Me) formed MnO_4^- to enhance oxidation efficiency by activated oxidation. SiC oxidation, essential step to improving MRR and surface quality of SiC substrate was observed to be activated in modified SiC slurry.

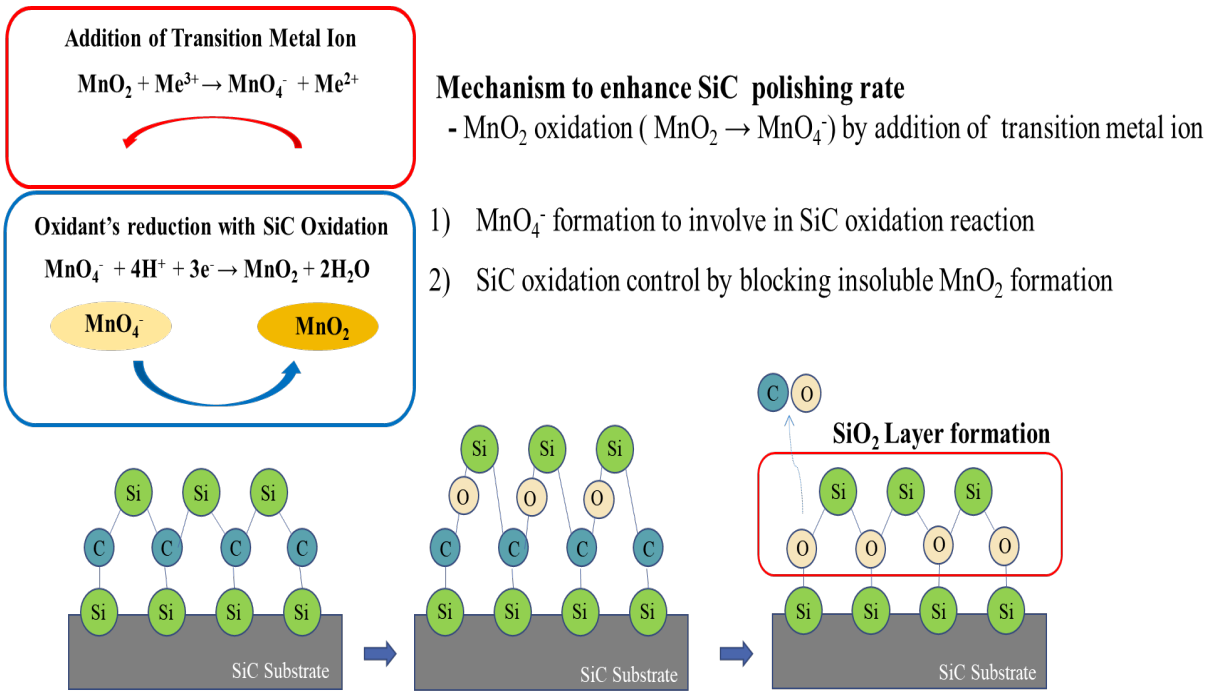


Fig. 1. Schematic diagram for explaining a role of adding transition metal ion into modified SiC slurry to enhance SiC polishing rate.

Fig. 2 exhibited MRR values and platen temperature on Si-face and C-face of CMP-processed SiC substrates with using commercial slurries and modified slurry proposed in this study. MRR value as an important factor to determine a polishing efficiency was measured on Si-face and C-face of SiC substrate. MRR was calculated by measuring the front surface of SiC wafers before and after the CMP process using a thickness gauge. The MRR value of CMP-processed SiC substrate with all slurries on C-face was definitely higher(~2X) than on Si-face. MRR value of SiC substrate with using modified slurry was slightly higher than those with using commercial slurries. The platen temperature of the CMP process using the modified slurry exhibited lower than commercial slurries.

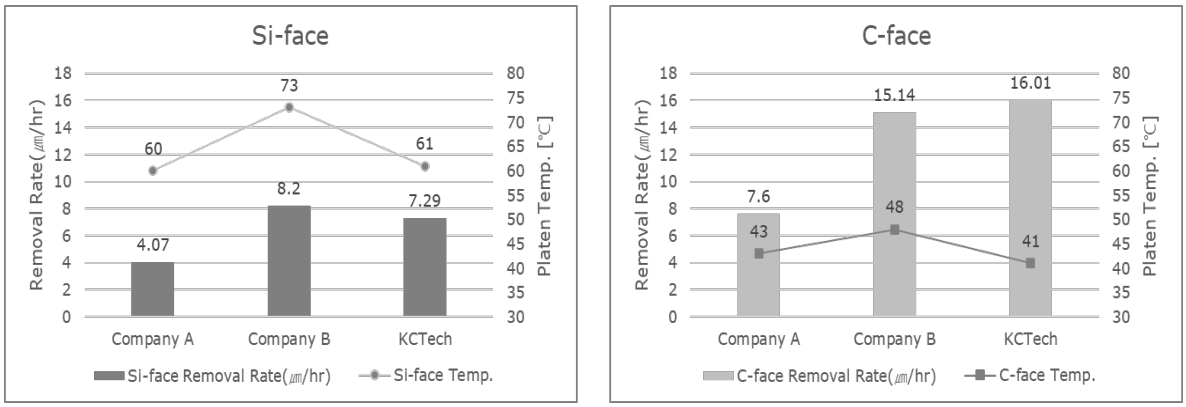


Fig. 2. The MRR values and platen temperature on Si-face and C-face of CMP-processed SiC substrates with using conventional slurries and modified slurry proposed in this study.

The surface morphology images and roughness data observed by atomic force microscope (AFM) analysis for SiC substrate processed by slurry proposed in this study and conventional slurries are shown in Table 1 and 2. The roughness of SiC substrate with using the modified slurry proposed in this study was definitely lower than commercial slurries. While roughness of SiC substrate with using conventional slurries showed above 0.1 nm on Si-face and 0.15-0.22 nm on C-face, SiC substrate with using the modified slurry had better roughness value(0.045 nm on Si-face and 0.15 nm on C-face).

Table 1. The surface morphology images and roughness data observed by AFM analysis for Si-face of SiC substrate processed by slurry proposed in this study and substrates processed by conventional slurries.

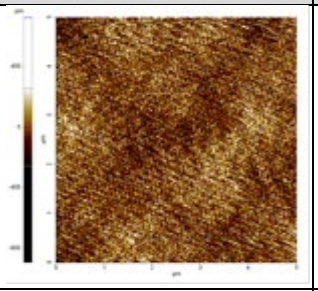
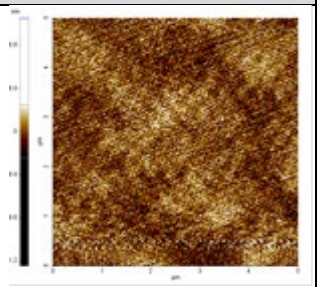
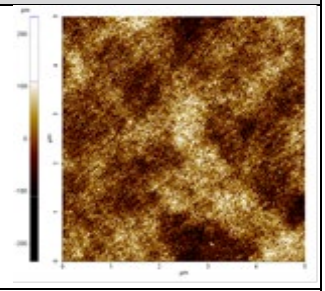
	Company A	**Company B**	**KC-Tech**
AFM Image			
Roughness [㎚]	0.105	0.100	0.045

Table 2. The surface morphology images and roughness data observed by AFM analysis for C-face of SiC substarte processed by slurry proposed in this study and substrates processed by conventional slurries.

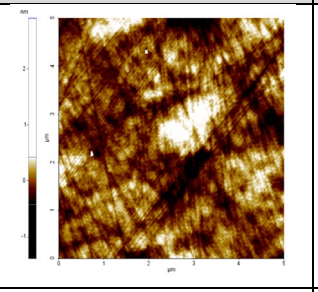
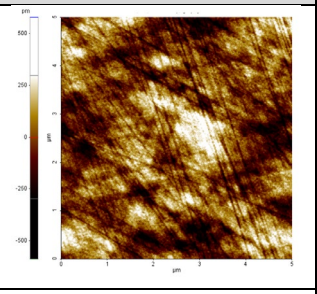
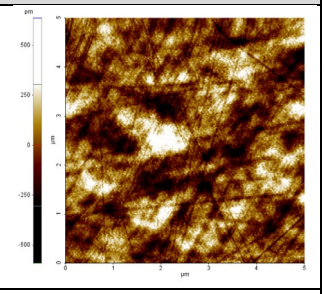
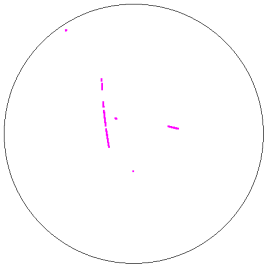
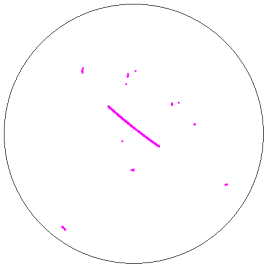
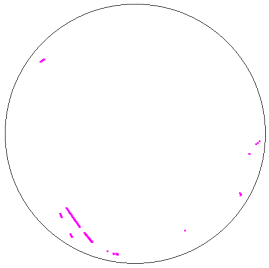
	Company A	**Company B**	**KC-Tech**
AFM Image			
Roughness [㎚]	0.216	0.152	0.155

Table 3 showed scratch mapping analysis data of SiC substrate processed by slurry proposed in this study and substrates processed by conventional slurries after RCA cleaning. In terms of total length of scratch, three SiC substrates exhibited almost similar value showing no significant difference.

Table 3. The scratch data observed by Candela analysis for SiC substrate processed by slurry proposed in this study and substrates processed by conventional slurries.

	Company A	Company B	KC-Tech
Scratch Map			
Total Length	47 mm	69 mm	52 mm

Summary

The modified SiC slurry for CMP process was compared with commercial slurries in terms of surface roughness, MRR, scratch formation. SiC substrate with using modified slurry exhibited was slightly higher MRR value and lower platen temperature than those with using commercial slurries. The C-face roughness of the SiC substrate using the modified slurry was similar to that of Company B, but the Si-face roughness of the SiC substrate using the modified slurry proposed in this study was definitely lower than that of the commercial slurry. The addition of transition metal ion into the slurry enhanced oxidation efficiency of SiC crystal surface and improved MRR and the quality of SiC surface.

Acknowledgements

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References

[1] Qixiang Zhang, Jisheng Pan, Xiaowei Zhang, Jiabin Lu, Qiusheng Yan: Wear Vol. 472-473 (2021), p. 203649

[2] Yu, S. Hu, J.J. Xu, L.L. Liu, M. Liu, E. Givens, J Leighton: Mater. Sci. Forum Vol.1062 (2022), p. 229

[3] Chi-Hsiang Hsieh, Che-Yuan Chang, Yi-Kai Hsiao, Chao-Chang A. Chen, Chang-Ching Tu, Hao-Chung Kuo: Micromachines Vol. 13 (2022), p. 1752

[4] Wang, Weilei, Weili Liu, and Zhitang Song: ECS Journal of Solid-State Science and Technology 10.7 (2021): 74004

[5] R. Vacassy, A. Gibson, A. Titov, A. Walters, T. Shindo: Sci Forum Scientific, Vol. 924, p. 539-542, June 2018

[6] Fu Sufanga, Yao Jianguo, Ma Lijie and Su Jianxiub: Advanced Materials Research Vol. 1027 (2014), p. 213-216

[7] Jianxiu SU, Zhuqing ZHANG, Xinglong LIU, Zhixiang LIU and Qigao FENG: Advanced Materials Research Vol. 703 (2013) p. 90-93

[8] Lagudu, U. R. K., Isono, S., Krishnan, S., and Babu.: Physicochemical and Engineering Aspects, Vol. 445, p. 119–127, 2014.

[9] Yin, T., Kurokawa, S., Ohnishi, O., Yamazaki, T., Wang, Z. D., and Tan, Z.: Advanced Materials Research, Vols. 591–593, p. 1131–1134, 2012.

[10] Kurokawa, S., Doi, T., Ohnishi, O., Yamazaki, T., Tan, Z., and Yin, T.: Materials Research Society Symposium Proceedings, Vol. 1560, p. 39–47, 2013.